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Provides procedures for planning and conducting durability tests. This TOP applies to all items for which durability criteria exist or can be developed, and for which a durability test is required by test directive.

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UNCLASSIFIED TITLE

US ARMY TEST AND EVALUATION COMMAND TEST OPERATIONS PROCEDURE 'DURABILITY'.

ABSTRACT

(U) THIS TOP PROVIDES GUIDELINES FOR PLANNING AND CONDUCTING DURABILITY TESTS. IT APPLIES TO ALL ITEMS FOR WHICH DURABILITY CRITERIA EXIST OR CAN BE DEVELOPED, AND FOR WHICH A DURABILITY TEST IS REQUIRED BY TEST DIRECTIVE.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

AMSTE-RP-702-100
*Test Operations Procedure 1-2-502 19 December 1984
AD No.

DURABILITY

*This TOP supersedes TOP 1-2-502 dated 14 September 1972; MTP 9-2-503 dated 1 August 1971; and MTP 10-2-502 dated 1 September 1971.

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1. SCOPE. This TOP provides guidelines for planning and conducting durability tests. It applies to all items for which durability criteria exist or can be developed, and for which a durability test is required by test directive.

Durability is defined as the probability that an item will successfully survive until its projected service life or rebuild point (whichever is the more appropriate durability measure for the item) without a durability failure. Such a failure is a malfunction that precludes further operation of the test item and is so serious (in terms of cost or time to restore) that the item must be replaced or rebuilt. A durability failure may also include the following not economically repairable criteria when (1) failures have become abnormally frequent and time-consuming or (2) the item shows such overall deterioration that further maintenance to retain it in serviceable condition is not warranted.

Durability is a special case of reliability as defined in MIL-STD-721C.1* Reliability is the probability that an item will perform its intended function for a specified interval under stated conditions; in durability measurement, the specified interval is the service life of the item. Both reliability and durability are mathematical measures with precise meanings, and the terms must be used with care. Durability must not be confused with endurance which is a general term concerned with a subjective evaluation of an item's ability to perform satisfactorily under typical field conditions for long periods of time.

Two specific documents are required to initiate planning for durability assessment of any item: the operational mode summary and mission profile (OMS/MP) and a durability failure definition. Both must be provided to the testing activity by TECOM. The OMS/MP will be developed by the combat developer in coordination with the materiel developer and the independent evaluators. It will be provided to the operational and developmental testers for review and comment. The failure definition is developed jointly by the combat and materiel developers.

The OMS/MP must describe in quantitative terms the typical conditions and environment in which the item will perform. For items expected to operate in several environments, the percentage of each expected environment must be stated (e.g., for wheeled vehicles: percent cross-country, percent primary roads, percent secondary roads, percent towed load, etc.). In some instances, the anticipated use of the item may cover such a broad spectrum of environments that it will be more convenient to divide the item operational modes into two or more conditional modes. If, for example, an item is expected to operate under arctic, tropic, and desert conditions, depending on assignment, these can form the basis for three conditional modes with a separate durability requirement specified for each. This would then necessitate three separate durability tests.

The statement of durability failure must precisely define the conditions that will exist when the service life of the item is considered terminated.

*Footnote numbers correspond to reference numbers in Appendix B.

A durability requirement will reflect the intended Army use of the test item as stated by the Required Operational Capability (ROC), or other established criteria. The requirement will be stated in a measure appropriate to the item: in hours, cycles, miles, rounds, or any other measure that reflects the length of the item service life. The remainder of this document will refer to this measure as time of operation but will be interpreted to mean the appropriate measure of service life.

This document is intended for use in assessing durability of different commodity items. The great variety and complexity of this materiel makes it impractical to prepare procedures, checklists, or questionnaires precisely matched to each commodity type or category. For this reason, material as presented herein is general; test personnel should prepare procedures and lists necessary for the specific item being considered.

2. FACILITIES AND INSTRUMENTATION. As required to represent the operational and environmental conditions expected to be encountered by the item in the field.

Because of the wide variety of commodity items covered by this document, it is not practical to list all necessary equipment. The actual equipment required will be determined by the item being tested. The following listing includes items common to testing various commodity items.

2.1 Facilities.

ITEM

Measuring tapes
Maintenance and lubrication facilities
Appropriate materials-handling equipment
Appropriate transportation facilities
Compressed air source
Shock and vibration test facilities
Laboratory analysis facilities
Water pumping capabilities
Climatic test chambers
Scales (machinist's)
Weighing scales
Stopwatches
Still camera and film
Motion picture camera and film
Flashlights

2.2 Instrumentation.

ITEM

Tachometer
Tension dynamometer
Manometer
Anemometer
Barometer
Thermometers (including wet and dry bulb)
Pressure gages
AC and DC voltmeters
Wattmeters (one- and three-phrase)
Ohmmeters
Ammeters
Light meters
Sound intensity meter per ASA S1.4-1961
Feeler gages
Inside and outside micrometers and calipers
Octave band analyzer per ASA S1.6-1960
Universal tester
Abrasion tester
Tensile strength tester
Dielectric strength tester
Oscilloscopes
Tape recorders

3. REQUIRED TEST CONDITIONS.

a. Perform preliminary and safety inspections of the test item, appropriate to the particular commodity, unless accomplished as part of other testing.

b. Obtain and analyze OMS/MP statement to ascertain whether it precisely defines the operating environment for the item. If not, request clarification from the originator.

c. Design a test in which the item will be operated in as close to actual field conditions as possible for a specified percent (e.g., 20%) of the anticipated service life of the item. When the OMS/MP specifies several environments by percent, the test must be performed with the specified percentage of each environment. Guidance for cycle design for wheeled and tracked vehicles is provided in TOP 2-2-5062 and ITOP 2-2-506(1).3

d. Obtain and analyze the statement of durability failure to ensure that it completely and precisely defines the conditions that exist at the time of service life termination. The statement may take the form of a catalog of mechanical malfunctions, a value limitation of labor required to correct a malfunction, a limitation of the cumulative cost or man-hours expended throughout the life of an item, or any other criteria or combination of criteria that will ensure there is no ambiguity about when service life has ended.

e. Develop a data-collection plan that will obtain the information necessary to identify the occurrence of a durability failure.

f. Conduct the durability test simultaneously with other test operations to the maximum extent possible. It will usually be possible, as a minimum, to develop reliability and maintainability data at the same time the item is being operated for durability testing.

3.1 Operator/Maintainer Training and Familiarization.

a. Ensure that all test personnel are thoroughly familiar with all local test activity safety precautions and procedures and those standing operating procedures (SOP's) appropriate for the commodity item being tested.

b. Ensure that all test personnel are oriented in accordance with MTP 10-2-501.4

c. Test personnel should review other appropriate documents as referenced in Appendix B of this TOP for general assistance, guidance, and authority.

d. Record the rank, MOS, past experience, and extent of additional training required for each test team member.

3.2 Checklists and Questionnaires. In preparation for the durability assessment, test personnel should do the following:

a. Review all applicable requirements documents, determine and record all appropriate requirements and limitations as pertains to the following:

(1) Durability
(2) Reliability
(3) Maintainability
(4) Availability

b. Review paragraph 4.2 of this TOP, all applicable documents as referenced therein, appropriate draft technical manual(s), and other pertinent instructional material as furnished with the test item.

The purpose of this review is to determine before testing, all areas or components subject to conditions of excess wear, deterioration, or general degradation as a result of usage and environmental exposure. Proceed as follows:

(1) Prepare a questionnaire or checklist for the commodity item being tested. The list should be included in the test plan and should itemize all components and features to be considered in the durability assessment. In addition, the checklist should include the following:

(a) Appropriate inspection intervals for each point to be considered
(b) Type of degradation anticipated
(c) Initial and limiting dimensions and clearances for all critical components and features
(d) Any limitations pertinent to the component or feature
(e) Other information or comments considered useful in accomplishing a valid and meaningful assessment

(2) Prepare and maintain a test log throughout the testing program. The log should indicate the following:

(a) All maintenance and service accomplished (scheduled or unscheduled)
(b) Total accumulated test item operating time
(c) All failures and malfunctions
(d) Time between failures
(e) Indicate the following for each failure/malfunction:

1 Failing component and serial number
2 Accumulated operating time for the test item and the failing component
3 Seriousness of the failure; effect of the failure with regard to overall test item effectiveness, down time, and other appropriate considerations
4 Reason for the failure (special note should be made concerning those failures attributable to a lack of durability)
5 Manner in which the malfunction was detected and the methods used to locate the failing component
6 Corrective action taken; active correction time and manhours for corrective action
7 Any recommendations for preventive maintenance or other measures intended to improve reliability
8 Physical location of failed component

(f) Other information and data as appropriate

4. TEST PROCEDURES.

4.1 Initial Inspection. A pretest inspection is necessary to determine the condition of the test item and its associated system support package (SSP) when they arrive at the test site. This should include test item physical characteristics, an operator training and familiarization program, and general guidance for use in preparing necessary checklists, questionnaires, and the test log. Post-operational inspections should also be conducted to determine degradation and deterioration.

a. Visually inspect the shipment; record the following:

(1) Nomenclature
(2) Model number
(3) Serial number
(4) Manufacturer
(5) Accessories and tools supplied
(6) All instructional material, literature, and draft technical manuals
(7) Any indication of improper preservation or packaging (refer to applicable specification/standard)
(8) Any indication of damage incurred during shipment
(9) Noted discrepancies and potential safety hazards

b. Carefully examine the test item, and record any evidence of defects in workmanship, construction, and materials. Methods of construction should indicate sound design and good shop practice. Materials should be new and as authorized or specified. Refer to specifications such as the system specification or prime item product fabrications specification for information about

manufacturing requirements agreed upon by the manufacturer and the Government. Visual inspection shall concentrate on the following:

(1) Fiberglass/plastic/rubber shall be neatly molded and free from roughness, irregularities, foreign material or detrimental defects. Other than as specifically permitted by the applicable specifications, the surface shall not contain porous areas or bubbles.

(2) Wood shall be sound and free from defects other than as specifically permitted by the applicable component specifications. Wood shall be neatly and accurately cut, contoured, finished, and drilled. Where used, caulking shall be neat and shall present a uniform appearance.

(3) Aluminum and metallic materials should be free from kinks, excessive scratches, and sharp bends. Corners shall be square and true with joining surfaces. All joints of framing and plating shall be aligned and fitted without the use of fillers or devices to hide or mitigate structural defects. All burrs and rough edges shall be ground smooth. The test item shall be free from sharp edges.

(4) Castings and forgings shall be uniform in quality and condition and shall be free from patching, warping, tears, cracks, ruptures, imbedded scale, segregations, or other defects which would render them unsound for use, or detrimentally affect the test item's suitability for its intended purpose and continued testing.

(5) Fabrics shall not be torn, cut, or punctured, nor shall there be any weak areas, broken or missing yarns, multiple floats or open places, frayed or scalloped edges. Colors shall be uniform.

(6) Joints, connections, and attachments shall be in accordance with applicable specifications and adequate to ensure strength. All seams shall be smooth, uniform, and free from faults, dirt, sand, flux, slag, or other extraneous material.

(7) Painted surfaces should be adequately covered, even and smooth in finish, texture, and appearance, and consistent in color.

(8) Bearings, shafts, and similar components shall not be loose/worn, and will operate smoothly without binding or jamming.

c. Photograph the shipment; particular attention should be given to any damaged area and potential safety hazards. (Liberal use should be made of photographic facilities in documenting initial test item condition.)

d. When test items must conform to standard durability procedures, ensure that test courses or laboratory procedures are in accordance with specified requirements.

e. For assistance in determining initial test item component condition and characteristics, test personnel should consult the Military Standards, Federal Specifications, and TOPs/MTPs referenced in Appendix B.

f. Discrepancies discovered during the initial inspection shall be corrected whenever possible, or an appropriate notation shall be made in the test log for possible consideration during the data reduction phase. All discrepancies shall be reported on an EPR in accordance with DARCOM Reg 70-13.5

g. Information and data obtained as a result of the above procedures should be supplemented as necessary to ensure that the initial test item condition is well defined and that no test item damage exists before testing. Checklists developed in accordance with this document should be used in accomplishing this review.

4.1.1 Inventory Check

a. Conduct an inventory against the System Support Package (SSP). Record evidence of the following:

(1) Missing maintenance literature or draft technical manuals.

(2) Shortages in repair parts, accessories, or tools.

b. Submit an Equipment Performance Report (EPR) noting the shortages or discrepancies in accordance with the applicable procedures of DARCOM Reg 70-13.

4.1.2 Physical Characteristics. Conduct procedures as specified in the appropriate TOP/MTP (e.g., TOP 2-2-5006, 3-2-5008, 4-2-5009, etc.).

4.2 Durability Test. This test is conducted to determine the durability of the test item in terms of its ability to achieve its stated service life while performing under all conditions for which it is designed, in approximately realistic proportions.

The evaluation should consist of a series of inspections, operations, observations, and comparisons. These actions are primarily intended to accomplish the following:

a. Determine initial test item condition, thereby establishing a base for use in making comparison evaluations.

b. Monitor changes in test item condition resulting from the effects and influences of continued operation and environmental exposure. Appendix A contains information about conditions and factors that may affect test item durability.

c. Obtain information and data necessary for use in establishing a relationship between test item degradation and usage or exposure time, for predicting reliability, availability, maintainability (RAM), and for use in determining compliance with established durability requirements.

d. All equipment malfunctions that occur during testing shall be noted in the equipment test log and shall be reported in an EPR in accordance with DARCOM Reg 70-13.

Extract standards directly from the requirements documents or other authoritative sources given in the test directive. A complete criteria statement will include

the required durability, a stated service life, and the conditions required by the OMS/MP. Confidence levels are not normally specified in source documents; therefore, they must be selected by the test director and will represent a compromise between minimizing risk and increased testing cost. The conditions required by the OMS/MP may be described in a general statement that will be amplified in the description of the test method.

4.2.1 Method. Durability testing generally is carried out by operating a group of test items under conditions that duplicate field conditions as closely as possible until durability failure occurs. In some cases, the test may be terminated before all items have failed; even items that have not yet sustained a durability failure, however, can be expected to be near the end of their service life and unsuitable for further use. The description of the test method must contain the following elements:

a. Description of the item OMS/MP and the test environments and conditions that will be used to approximate field conditions. This must include the percentage breakdown for each operating environment, the duration, the order in which each condition will occur, and other special instructions as necessary to make the test environments simulate the OMS/MP.

b. Definition of the conditions that represent a durability failure. This definition must be comprehensive and all-inclusive so that it will be immediately apparent during testing whether an item has sustained a durability failure.

c. Statement of the number of items in the sample. Sample size is computed on the basis of the durability criteria and desired confidence level. The minimum sample is the number of items that will demonstrate the required durability at the desired confidence level when no durability failures occur before reaching required service life.

d. Explanation of the system support package (SSP) to support the durability test. This includes the plan for scheduled maintenance and the limits of allowable unscheduled maintenance until durability failure. After a durability failure, no additional maintenance is performed and the item is disposed of as directed by TECOM or the developer.

4.2.2 Data Required. Data required are all those parameters necessary to identify a durability failure and the time, in terms of service life, when the failure occurred. The required data are usually collected as part of logistic support as prescribed in TECOM Suppl 1 to DARCOM Reg 700-1510, but must include records of:

a. Item use in terms of hours, miles, cycles as appropriate, courses, speed, loading factors, environment, and other operating conditions.

b. Failure including type, time of occurrence, circumstances, and action taken. Metal parts failures should be examined by the metallurgist, and failure mode and likely cause of failure identified.

c. Modifications and maintenance performed, including time of occurrence, circumstances, and parts and labor expended.

5. DATA PRESENTATION.

a. In compiling data as specified herein, test personnel should indicate clearly by narrative descriptions, photographs, and actual dimensions any condition of test item degradation or deterioration. All photographs and other data will be properly identified and labeled. Data shall be obtained for each item tested.

Data obtained shall be compared with durability characteristics requirements as specified in the appropriate criteria. Test data obtained from commodity items undergoing the same test will be compared. When evaluations are repeated following test item repair and continued usage, the data obtained will be compared with previously obtained data, and when definite differences occur, the conditions that caused the differences and the degree of difference will be summarized along with appropriate comments of the test personnel.

The presentation shall conclude with a summarization of the adequacy of the test item durability characteristics and any recommendations for improvement.

b. Analytical Plans For Durability Testing. Analytical plans for durability testing are designed to develop a statement in the form of a lower confidence limit on durability based on test results. Two factors complicate the analysis of durability test results: first, usually only small sample sizes are possible because the durability testing requires extended periods of time and destroys the tested items; second, durability failures occur at the end of the service life of the item and very little is usually known or can be assumed about the statistical distribution of durability failures. In all durability testing, the test planner must consult analytical personnel and, with their assistance, design an analytical plan appropriate to the item being tested.

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APPENDIX A

CONDITIONS AND FACTORS AFFECTING DURABILITY

Determine and record test item degradation resulting from usage, handling, and environmental exposure. Evaluate as indicated below:

a. Inspect test item at frequent intervals throughout all appropriate commodity tests. The frequency of these inspections will depend on the item being considered and should be determined by the testing activity before testing. In general, the test item should be inspected as follows:

(1) Immediately following each major operational test
(2) After the endurance evaluation
(3) After each environmental evaluation
(4) Upon completion of mobility tests (when appropriate)
(5) After the transportability evaluation
(6) After malfunction of any major test item component or feature
(7) As otherwise considered necessary for the item being tested

NOTE: Inspections following endurance, environmental, and transportation evaluations are normally quite revealing since the test item may have sustained greater degradation effects during these periods.

b. Test personnel should examine all points of potential degradation and record all appropriate data and comments concerning test item conditions. Consideration should be given to the questions, comments, statements, and procedures listed below. As previously noted, the scope of this document precludes precise coverage of individual items. In preparing questionnaires and checklists, test personnel should note that these lists must be tailored to suit the test item.

I. Maintenance and Service.

a. Test personnel shall consult TECOM Supp 1 to DARCOM Reg 700-15; review all draft technical manual(s) and other maintenance literature, and ensure that all appropriate maintenance and service have been accomplished. Guidance on evaluating item maintenance characteristics is provided in MTP 6-2-504, TOP 7-3-507, and MTP 10-2-507.11-13

b. Complete maintenance and service records shall be maintained. For information concerning these records refer to 3.2.b(2).

II. Conditions of Wear.

a. Inspect the test item as necessary to determine conditions of wear resulting from usage, handling, or other influencing factors. When possible, determine the extent of wear by actual measurement. Accurate determination is essential, especially in critical areas such as bearings, shafting, and similar components. In many instances, it is not possible to determine actual wear conditions without disassembling the test item. In other instances, acceptable approximations can be made using experienced personnel, special techniques, and appropriate test equipment. The extent of disassembly will depend on the item being considered, certain regulatory documents, and local test activity policy.

The test director shall arrange for complete or partial disassembly as appropriate for the particular test item. Quantitative wear data may be obtained by dimensional changes or by weight loss as well as by description of visual appearance.

b. Wear can normally be anticipated in the following areas:

(1) Bearings and shafting
(2) Shaft seals and packing glands
(3) Piston rings and cylinder liners
(4) Vehicle tires, wheels, and brake linings
(5) Universal joints and flexible couplings
(6) Vehicle landing gear, pintle, lunette, and fifth wheel
(7) Valve seats and discs
(8) Wearing rings
(9) Operating mechanisms and linkages
(10) Walkways, steps and ladder rungs, and work surfaces
(11) Pulleys, sheaves, sprockets, belts, and chain
(12) In evaluating clothing and similar items, special consideration should be given to all contact and wearing areas including toe, heel, and sole areas of footwear, knee, elbow, pockets, seat, and inseam areas for other items.
(13) Normally, surfaces in moving contact with other surfaces are subject to wear. Components in contact with abrasive surfaces or materials are especially subject to rapid degradation resulting from wear.

III. Paint, Finishes, and Protective Coatings. Thoroughly inspect all appropriate test item components, particularly all exposed surfaces. Give special consideration to those surfaces in moving contact with other surfaces and to all surfaces which are normally exposed to heat, solvents, chemicals, dust, sand, salt spray or other deteriorating influences. Record and describe any indication of the following:

a. Chipping
b. Peeling
c. Cracking
d. Pitting
e. Softening
f. Loss of resiliency
g. Mildew, fungus, insect, or animal-inflicted damage
h. Wear
i. Scratches
j. Staining, fading, or other discoloration
k. Corrosion
l. Loss of luster or reflective properties when appropriate
m. Loss of waterproofing, thermal insulation, etc.
n. Other

IV. Joints and Seams. Inspect all joints and seams. When doubt exists, testing shall be accomplished as necessary to determine actual condition. Consider the following:

a. Leakage
b. Opening or separation
c. Cracking

d. Breakage or tearing
e. Loose or missing bolts, rivets, or other fasteners
f. Gasket failure or damage
g. Loose stitching, fraying, or other damage
h. Any indication of weakening or other potential failure

V. Fatigue. Thoroughly inspect all items or components normally subjected to loading conditions or movement from which fatigue could result. Nondestructive inspection methods are usually required to detect fine surface and near-surface cracks. Magnetic particle, penetrant, eddy current, ultrasonic, or radiographic inspection should be used, as appropriate. Consider the following:

a. Flexing or deformation
b. Fluctuating loads, pressures, or temperatures
c. Shock loads
d. Vibration
e. Oscillation
f. Other

VI. Clearances and Critical Dimensions. Review the draft technical manual, and inspect the test item to ensure that dimensional tolerances have not been exceeded. Make special note of any item or component which has reached or is rapidly approaching the maximum wear replacement limits.

VII. Alignment. Determine any condition of twisting, warpage, distortion, or misalignment. The condition may be obvious upon visual inspection, but the actual amount should be determined by measurement. Consider the following:

a. Noisy operation
b. Vibration
c. Excessive wear
d. Binding or jamming
e. Poor tracking characteristics
f. Difficulty in maneuvering or using
g. Improper fit
h. Discomfort
i. Leakage
j. Loss of focus or resolution
k. Other malfunctions

VIII. Settings and Adjustments. Inspect the test item at periodic intervals throughout the testing program to ensure continued ability to retain preselected settings and adjustments.

IX. Electrical Systems. Inspect electrical systems and components for degradation caused by the following:

a. Overheating
b. Overloading
c. Arcing
d. Insulation breakdown
e. Connection or terminal separation
f. Any item which demonstrates a shortened life span
g. Other

X. Operating Fluids. Throughout all testing procedures, monitor all test item operating fluids. Consider the following:

a. Leakage
b. Contamination
c. Color changes
d. Increased consumption rates
e. Changes in operating fluid levels
f. Changes in operating temperatures, pressures, and flow rates
g. Damage caused by fluids outside their normal area of operation
h. Spectrometric Oil Analysis Program (SOAP) for periodic wear metals analysis of engines
i. Other

XI. Overloads and Loss of Power. Ensure that degradation has not occurred in power output capabilities. Consider the following:

a. Decrease in production output or quality
b. Increased fuel or oil consumption
c. Smoking
d. Overheating
e. Vibration
f. Noisy operation
g. Stalling, sluggish operation, decreased speed or acceleration characteristics
h. Crushing, bulging, elongation, rupture, distortion, breakage, or other failure
i. Other

XII. Spoilage, Contamination, and loss of Nutritive Value. Rations and foodstuffs are susceptible to deterioration and degradation from numerous factors. The influencing factors are normally time and environment. In evaluating foodstuffs, consider those factors discussed in this paragraph through 4.32. Laboratory and other testing shall be accomplished as necessary to ensure that the commodity is safe for consumption, that the nutritive value is retained, and that the item's palatability characteristics are not decreased or destroyed.

XIII. Handling and Shipment. Determine any damage and the extent thereof due to handling, packaging, and transportation. Direct special attention to the following:

a. Lifting eyes and pads
b. Points of contact with lifting slings, straps, blocking, and the shipping container
c. Damage from vibration or shock
d. Damage or deterioration from environmental influences
e. Other

XIV. Improper Usage. Determine and record any damage from operator error. Describe in detail the error and extent of damage. Distinguish between designed overload operating mission requirements and test item abuse.

XV. Labels, Instruction Plates, and Markings.

a. Record inadequate or incorrect instruction plates, labels, warning plates, or posted limitations.

b. Record any loss of or damage to labels, instruction plates, and markings. Ensure permanence and legibility.

XVI. Dissimilar Metals. Examine the test item for damage or deterioration from contact of dissimilar metals. Degradation normally occurs as corrosion, erosion, or pitting. The extent of damage will vary with time, materials involved, and environment.

a. Contact between dissimilar metals presents a potential point of degradation. When these metals are far apart in the galvanic series, this condition becomes more severe (see Table A-1).

TABLE A-1
GALVANIC SERIES OF METALS AND ALLOYS

Anodic End (most easily corroded)

Group	Metal
I	Magnesium
	Magnesium alloys
II	Zinc
	Galvanized iron or steel
	Aluminium
III	Cadmium
	Cadmium-plated iron or steel
	Mild steel
	Wrought iron
	Ni resist
	Lead-tin solders
	Lead
	Tin
IV	Chromium
	Admiralty brass
	Aluminium bronze
	Red brass
	Copper
	Silicon bronze
	Phosphor bronze
	Beryllium copper
	Nickel
	Inconel
	Monel
	Type 400 corrosion-resisting steel
	Type 300 corrosion-resisting steel
	Titanium
V	Silver
	Gold
	Platnium

Cathodic End (least susceptible to corrosion)

b. Damage from contact of dissimilar metals normally increases in the presence of certain chemicals, salt water, or salt atmospheres. Marine equipment and facilities are very susceptible to damage from this condition.

XVII. Animals and Insects. Record any damage from the actions of animals or insects.

XVIII. Fungus. Record any damage or degradation from fungus. It should be noted that damage from fungus is normally more severe in high humidity, warm atmospheres, and the presence of inorganic salts. The following materials are subject to damage from fungus or fungus metabolic waste products:

a. Cotton
b. Wood
c. Linen
d. Cellulose nitrate
e. Regenerated cellulose
f. Leather
g. Paper and cardboard
h. Cork
i. Hair and felts
j. Natural rubber
k. Plastic materials containing linen, cotton, or wood flour as a filler
l. Vinyl films containing fungus-susceptible plasticizers
m. Formulations of elastomers containing fungus-susceptible catalysts, plasticizers, or fillers
n. Packaged rations
o. Grease, oils, and many hydrocarbons
p. Paint and varnishes that contain susceptible constituents
q. Other materials

XIX. Dust and Sand. The following list indicates conditions which may result from dust and sand:

a. Damage from abrasion (loss of optical and reflective properties, erosion, scoring of bearings and shafting, etc.)

b. Blockage and fouling of moving parts as well as radiator and heat exchanger core components

c. Contamination of packaged rations, fuels, lubricants, and other materials

d. Deposits collecting and holding water, thereby increasing corrosion problems

e. Deposits forming electrically conductive bridges with resultant shorts or other failures.

XX. Salt Fog and Atmosphere. Exposure to atmospheres containing salt may result in degradation as follows:

a. Damage caused by abrasion
b. Binding or other malfunctions caused by deposits
c. Deterioration of material
d. Increased conductivity
e. Corrosion
f. Moisture damage
g. Contamination
h. Galvanic action (refer to dissimilar metals)

XXI. Ozone. Certain materials are subject to damage from the effects of ozone. Rubber and some synthetics are considered susceptible. The following list indicates typical conditions resulting from ozone:

a. Chemical reactions
b. Crazing or cracking
c. Granulation and embrittlement
d. Accelerated oxidation
e. Loss of mechanical strength
f. Loss of insulation characteristics

XXII. Sunshine. Solar radiation may contribute additional heat load to vehicle cooling system components, and may subject materials to damage from exposure. The following lists some of the material damage which may result:

a. Discoloration and fading colors
b. Paint checking
c. Damage from heat
d. Decomposition
e. Deterioration especially to natural rubber and plastics
f. Embrittlement
g. Ozone formation

XXIII. Humidity. Exposure to warm, highly humid, atmospheres tends to accelerate fungal action, corrosion, and electrolysis; leads to moisture migration and penetration; and may increase the fouling factor on heat transfer surfaces/cores. The effects of high relative humidity may appear as follows:

a. Swelling
b. Rupture
c. Physical breakdown or decomposition
d. Polymerization
e. Loss of plasticizer or solvents
f. Increased weight resulting from absorption
g. Eventual shrinkage
h. Loss of electrical and mechanical strength and properties
i. Increased conductivity of insulators

XXIV. Rain and Water. These can cause damage as follows:

a. Erosion
b. Increased rate of corrosion
c. Damage to electrical systems and components
d. Contamination
e. Swelling and subsequent cracking or other deterioration

f. Material separation
g. Discoloration
h. Decomposition
i. Eventual shrinkage
j. Increased weight and loss of buoyancy
k. Accelerated fungal action
l. Various other conditions of deterioration

XXV. Wind. In addition to accelerated abrasive action by wind-blown materials, wind has the potential for increasing external vehicle cooling air re-circulation resulting in degradation of cooling system performance as a function of wind velocity and direction relative to the vehicle. The test item may be subject to structural damage from wind loading, fluctuating pressures, and other resultant forces.

XXVI. Ice, Sleet, Snow, and Hail. The test item may sustain damage from ice, sleet, snow, and hail. Consider the following:

a. Structural damage from loading
b. Blockage, binding, or other interference with component function
c. Abrasion
d. Moisture
e. Shorting of electrical components or systems

XXVII. High Temperatures. Test item components subjected to high temperatures may deteriorate or be damaged. Consider the following:

a. Permanent set of packing and gaskets
b. Binding or other damage from differential expansion of dissimilar materials
c. Melting, softening, and exudation
d. Thermal aging, cracking, bulging, checking, or crazing
e. Discoloration
f. Breakdown of electrical properties
g. Oxidation
h. Chemical reaction
i. Loss of lubrication properties
j. Evaporation or sublimation
k. Warpage
l. Weight change
m. Burning
n. Decomposition
o. Other

XXVIII. Low Temperatures. Under low temperatures, the test item may incur damage. Consider the following:

a. Differential contraction of dissimilar materials
b. Loss of resiliency of packings, gaskets, and other materials
c. Congealing of lubricants or other fluids
d. Damage from freezing
e. Discoloration
f. Other

XXIX. Altitude. Consider test item damage or deterioration from the effects of reduced pressures at high altitudes. It should be noted that problems resulting from high altitudes are often amplified by accompanying lower temperatures. Typical problem areas are as follow:

a. Rupture of pressurized containers
b. Leakage of gasses and fluids
c. Changes in material density and chemical properties resulting from low atmospheric pressure

d. Material contraction and embrittlement resulting from low temperatures
e. Congealing of fluids due to low temperatures
f. Heat transfer problems
g. Other problems as indicated for low temperature conditions

APPENDIX B

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